

*J. Bruce Gemmell*

# **Ore Shoot Targeting in the Gosowong Vein Zone, Halmahera, Indonesia.**

by  
**Daniel J. Olberg, B.Sc.**

**Submitted in fulfillment of the requirements  
for the degree of MEconGeol.**

**University of Tasmania  
August 2001**

## DECLARATION

This Thesis contains no material which has been accepted for a degree or diploma by the University or any other institution, except by way of background information and duly acknowledged in the Thesis, and to the best of The Candidates knowledge and belief, no material has been previously published or written by another person except where due acknowledgement is made in the text of the Thesis.

Signed: Daniel J. Allbery Date: 8 August 2001

## AUTHORITY OF ACCESS

This thesis may be made available for loan. Copying of any part of this thesis is prohibited for two years from the date this statement was signed; after that time limited copying is permitted in accordance with the *Copyright Act 1968*.

Signed: Daniel J. Allbery Date: 8 August, 2001

## ABSTRACT

Gosowong is located in the Maluku province of eastern Indonesia, on the north arm of the island of Halmahera. It is a classic example of a volcanic-hosted, low-sulfidation, epithermal <sup>Au</sup> quartz vein deposit. Due to the relatively short mine life, there is a very limited time frame for increasing ore reserves before mining ceases. Therefore a great emphasis has been placed on exploring the strike extent of the structure that hosts the Gosowong deposit. This mineralized structure is known as the Gosowong Vein Zone (GVZ) and has been traced along strike for 2 km, though the Gosowong deposit encompasses only a 400 m section of the total strike length. The primary aim of this study is to identify additional high-grade ore-shoots along the GVZ. To this end, a multi-faceted approach has been implemented incorporating structure, stratigraphy, vein textures, alteration zoning, fluid inclusions, and metal <sup>ation</sup> zoning, with the ultimate aim being to construct a system model that will allow predictive targeting of high-grade ore-shoots along the GVZ. Most data are presented on a longitudinal section of the GVZ.

High-grade mineralization at the Gosowong deposit occurs within two gently south-plunging ore shoots: the Quartz-Adularia zone (QA) and the Quartz-Chlorite zone (QC). The interplay between structure and stratigraphy is thought to be one of the main controls on the emplacement and distribution of high-grade mineralization at Gosowong. A distinct mappable volcanic stratigraphy has been recognized within generally intermediate to mafic coherent volcanic and volcanoclastic rocks of Miocene age. The preferential host rocks to faulting and subsequent quartz veining are the Gosowong Volcanoclastics, a package of resedimented volcanoclastic rocks with interbedded ignimbrite and andesitic lava. This unit dips moderately to the south, striking roughly perpendicular to the strike of the GVZ. The intersection between the volcanoclastic stratigraphy and the <sup>GVZ?</sup> Gosowong fault is thought to be the key factor in the deposition of high-grade mineralization. = GVZ  
= Gosowong  
fault

A study of quartz vein textures along the GVZ has shown that high-grade mineralization is generally developed in discrete shoots within lower grade or barren mineralization. The vein texture most commonly associated with high-grade mineralization is poly-compositional crustiform/colloform/cockade banding. The presence of bladed calcite pseudomorphs at various levels in the system is a positive indication of boiling, though they do not always carry significant Au grades. Banded chalcedony and phreatic breccia deep in the system perhaps indicates further <sup>ECONOMIC</sup> potential at depth.

Alteration zoning was mapped out with the use of a PIMA mineral analyzer. The alteration in the GVZ is typical of low-sulfidation, epithermal deposits. Illite-group minerals are

dominant in the ore horizons while propylitic assemblages are usually associated with weakly mineralized veining. Illite-group minerals and chlorite display a distinct zoning along the fluid flow pathway, from illite-chlorite  $\Rightarrow$  illite  $\Rightarrow$  illite-smectite  $\Rightarrow$  smectite-illite with decreasing depth. Alteration zoning mimics stratigraphy, as indicated by gently south plunging paleo-isotherms. Mineralizing fluids are postulated to have ascended the Gosowong fault and then spread out laterally along the permeable volcanoclastic horizon.

Fluid inclusion analyses indicate that mineralizing fluids have a typical epithermal signature: dilute (generally <1.0 eq. wt. % NaCl) and low temperature (generally 175-265°C). Coexisting vapor-rich and liquid-rich primary fluid inclusions indicate that boiling processes have taken place in the GVZ. Trapping temperatures in the QA zone suggest that quartz deposition took place 100-350 m below the paleo-water table. The variation in trapping temperatures between the QA (210°C) and the QC (236°C) may indicate multiple mineralizing events. Paleo-isotherms mimic the stratigraphy, plunging gently to the south, indicating a component of horizontal fluid flow through the permeable volcanoclastic units.

The GVZ appears to display most of the typical vertical metal zoning common in low-sulfidation epithermal systems: base metals dominant deep in the system, precious metals dominant at shallow levels. Base metal values are generally ~~very~~ low, averaging 125 ppm Cu, 53 ppm Pb, and 83 ppm Zn. Lead is the base metal most closely associated with Au mineralization. The distribution of high Au and Ag values indicates a gentle southerly plunge to the precious metal-rich horizon. Increasing Cu/Zn, Zn/Pb, and precious-metal/base-metal ratios may indicate vectors to ore-grade mineralization.

It appears that the southerly plunge of the strata, ore-shoots, paleo-isotherms, alteration zoning, and metal zoning may be in part due to the post-mineral tilting of the GVZ. It is believed that pre-mineralization deformation has rotated the strata approximately 25-30° to the south, while post-mineralization deformation has added an additional 10-15° to the overall rotation of the strata. Thus, deeper levels of the system are exposed closer to the surface on the north end of the GVZ.

A Gosowong specific "prospectivity matrix" has been constructed based on the sum total of the relative prospectivities of each of the components analyzed in this study. This matrix indicates that the most prospective area of the GVZ (outside of the Gosowong deposit area) is the area deep and to the south of the deposit. Additional, slightly less prospective areas have been delineated and a total of 5 drill holes have been targeted on these zones of interest.

## **ACKNOWLEDGEMENTS**

I would like to thank Newcrest Mining Limited for all the support, financial and otherwise, during the course of this study and to acknowledge the contributions of the large number of geologic staff, consultants, and field assistants who have worked on the Gosowong exploration program over the past 8 years. In particular, I would like to thank Dan Wood, Ray McLeod, Dave Pearson, and Grant Davey for their support of my educational endeavors. In addition, I would like to thank Bruce Gemmell for his guidance and useful draft reviews and to Handono for his assistance in drafting a number of the figures in this report.

## TABLE OF CONTENTS

<b>1. INTRODUCTION.....</b>	<b>13</b>
1.1 BACKGROUND.....	13
1.2 LOCATION.....	14
1.3 PREVIOUS WORK.....	14
1.4 AIM OF THE INVESTIGATION.....	15
1.5 SCOPE OF THESIS .....	16
<b>2. DEPOSIT GEOLOGY .....</b>	<b>21</b>
2.1 TECTONICS.....	21
2.2 DISTRICT GEOLOGY.....	23
2.3 DEPOSIT GEOLOGY .....	24
2.3.1 Lithology .....	24
2.3.2 Structure .....	26
2.3.3 Alteration .....	29
2.3.4 Mineralization.....	30
2.4 DEPOSIT HISTORY .....	33
<b>3. RESULTS OF THE INVESTIGATION.....</b>	<b>37</b>
3.1 STRATIGRAPHY & STRUCTURE .....	39
3.1.1 Introduction .....	39
3.1.2 Methodology .....	39
3.1.3 Stratigraphy.....	40
3.1.3.1 Ruwait Volcanics.....	40
3.1.3.2 Tobobo Sandstone.....	41
3.1.3.3 Gosowong Volcaniclastics .....	42
3.1.3.4 Ridge Volcanics .....	44
3.1.3.5 Environment of Deposition .....	45
3.1.3.6 Volcanological Model.....	45
3.1.4 Structure .....	47
3.1.4.1 Faulting.....	47
3.1.4.2 Bedding.....	51
3.1.5 Discussion.....	52
3.1.6 Conclusions .....	54

<b>3.2</b>	<b>QUARTZ VEIN TEXTURES</b>	<b>56</b>
3.2.1	Introduction	56
3.2.2	Methodology	56
3.2.3	Results	57
3.2.3.1	Crustiform/Colloform Banded Quartz	57
3.2.3.2	Bladed Calcite Pseudomorphs	60
3.2.3.3	Crystalline Quartz	62
3.2.3.4	Chalcedony	63
3.2.3.5	Vuggy Quartz	65
3.2.4	Textural Zoning Model	66
3.2.5	Conclusions	70
<b>3.3</b>	<b>ALTERATION ZONING</b>	<b>72</b>
3.3.1	Introduction	72
3.3.2	Methodology	73
3.3.3	Results	73
3.3.3.1	Kaolinite-Dickite $\pm$ Alunite	76
3.3.3.2	Smectite>Illite	77
3.3.3.3	Illite>Smectite $\pm$ Carbonate	77
3.3.3.4	Chlorite-Smectite $\pm$ Illite	78
3.3.3.5	Illite $\pm$ Chlorite $\pm$ Carbonate	79
3.3.3.6	Chlorite-Epidote $\pm$ Carbonate	80
3.3.4	Alteration: Conditions of Formation	81
3.3.5	Alteration Zoning Model	83
3.3.5.1	Hypogene Alteration	84
3.3.5.2	Steam-Heated Alteration	87
3.3.6	Conclusions	89
<b>3.4</b>	<b>FLUID INCLUSIONS</b>	<b>91</b>
3.4.1	Introduction	91
3.4.2	Methodology	91
3.4.3	Results	92
3.4.3.1	Heating Studies	93
3.4.3.2	Freezing Studies	96
3.4.4	Discussion	98
3.4.5	Conclusions	100
<b>3.5</b>	<b>METAL ZONING</b>	<b>102</b>
3.5.1	Introduction	102
3.5.2	Methodology	103
3.5.3	Results	104
3.5.3.1	Single Element	105
3.5.3.2	Metal Ratios	109
3.5.3.3	Vein Domain Scatter Plots	115
3.5.4	Discussion	117
3.5.5	Conclusions	121

<b>4. DISCUSSION .....</b>	<b>124</b>
<b>4.1 INTRODUCTION.....</b>	<b>124</b>
<b>4.2 INTEGRATED GOSOWONG MODEL.....</b>	<b>124</b>
<b>4.3 PROSPECTIVITY.....</b>	<b>128</b>
<b>5. CONCLUSIONS .....</b>	<b>131</b>
<b>6. RECOMMENDATIONS.....</b>	<b>135</b>
<b>REFERENCES.....</b>	<b>141</b>
<b>INDEX.....</b>	<b>145</b>
 <b>APPENDIX I: Drill Hole Locations .....</b>	 <b>147</b>
<b>APPENDIX II: GVZ Database.....</b>	<b>150</b>
<b>APPENDIX III: Cross-Section Geology.....</b>	<b>159</b>
<b>APPENDIX IV: PIMA Results.....</b>	<b>165</b>
<b>APPENDIX V: Fluid Inclusion/Petrology Results.....</b>	<b>187</b>
<b>APPENDIX VI: Prospectivity Matrix.....</b>	<b>221</b>